U.S. NUCLEAR REGULATORY COMMISSION STAFF EVALUATION OF
U.S. DEPARTMENT OF ENERGY ANALYSIS MODEL REPORTS,
PROCESS CONTROLS, AND CORRECTIVE ACTIONS

November 17-22, 2003
"General and Localized Corrosion of the Waste Package Outer Barrier"
ANL-EBS-MD-000002, Revision 2

December 8-12, 2003
"Commercial Spent Nuclear Fuel Waste Form Degradation Model"
ANL-EBS-MD-000015, Revision 2

January 12-16, 2004
"Drift Degradation Analysis"
EBS-MD-000027, Revision 2

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Enclosure

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EXECUTIVE SUMMARY

1.0 BACKGROUND

The U.S. Department of Energy (DOE), Office of Civilian Radioactive Waste Management, is planning to submit a License Application (LA) for a geologic repository at Yucca Mountain, Nevada, in December 2004. DOE has had problems in carrying out effective corrective action in the areas of models, software, and data. The U.S. Nuclear Regulatory Commission (NRC) staff has been concerned that recurring problems in the areas of models, software, and data will have an impact on the NRC staff's ability to effectively complete its evaluation of the LA.

To address these problems, DOE issued its Management Improvement Initiatives (MII) on July 19, 2002. The MII charts DOE's path forward for overall improvements. During the April 30, 2003, Quarterly Management Meeting, NRC staff expressed its concern about the lack of effective implementation of actions to correct recurring problems and noted that NRC staff intended to evaluate independently DOE's performance in developing Analysis Model Reports (AMRs). In performing this evaluation, a team was assigned to review a sample of DOE's AMRs. This report presents the results of the team's audit.

DOE has committed to submit a high-quality LA. A high-quality LA is one that contains the data and information necessary and sufficient to support the technical positions presented in the LA. Such data and technical information must be traceable, transparent, and technically appropriate for their use in the LA.

2.0 EVALUATION SCOPE

In order to assess the process being used by DOE to ensure the transparency of information in technical documents, the NRC Evaluation Team performed three targeted audits to independently evaluate the technical information in selected AMRs and supporting information considered to be of high or medium significance to repository performance. The technical information included field and experimental data, models, analyses, and justifications for any assumptions and conclusions presented by DOE. The staff used its risk insights baseline to select the AMRs believed to be of high or medium significance to repository performance. The team also evaluated the processes used in developing and controlling AMRs, and the effectiveness of recent corrective actions in eliminating recurring problems in the areas of models, software, and data. These audits occurred at the DOE Management and Operating Contractor, Bechtel SAIC Company, LLC (BSC), facility in Las Vegas, Nevada. BSC is DOE's prime contractor and has the overall responsibility for developing the LA for DOE.

This evaluation neither duplicates nor replaces the licensing review that NRC staff will conduct after DOE's submittal of its LA. Conclusions drawn from the results of this evaluation neither indicate NRC acceptance nor rejection of any DOE documents.

3.0 EVALUATION RESULTS

3.1 Good Practices

The team found a number of good practices during the evaluation. The team found DOE and BSC staff's support to be exceptional throughout the planning and performance of this evaluation. The preparations, information availability, and the willingness of personnel to discuss concerns, were outstanding. The team also found that technical information for the AMRs was greatly improved over what was available for the Total System Performance Assessment for Site Recommendation. The AMRs were updated, more comprehensive, and contained more data. The team found other good practices during the evaluation. Examples of these good practices are addressed in Section 4.0 of the report.

3.2 Technical Information

In order to assess the process being used by DOE to ensure the transparency of information in technical documents, the team evaluated three AMRs primarily in five main technical areas as described in the NUREG-1804, "Yucca Mountain Review Plan," Revision 2, July 2003: (a) System Description and Integration; (b) Data and Model Justification; (c) Data Uncertainty Characterization and Propagation; (d) Model Uncertainty Characterization and Propagation; and (e) Model Support. NRC regulations at 10 CFR Part 63 require DOE to support its LA for a proposed repository with technical bases. To review DOE's potential LA, the NRC staff will need to understand DOE's explanation of its technical bases and find that DOE has supplied sufficient technical information to justify that explanation. The team identified some concerns with both the clarity of explanation of DOE's technical bases presented in the AMRs evaluated and also with the presentation of adequate technical information necessary to support that explanation. These concerns are summarized under the following two categories.

A. In some cases, DOE did not explain its technical basis such that NRC staff could understand how DOE reached its conclusions. Because DOE's explanation of its technical basis was not clear, the team could not determine if the associated technical information was adequate. Examples of this situation follow:

  - DOE selected a single value or a portion from a range of data without sufficient justification. Examples can be found in Sections 5.2.2 and 5.3.3 of this report.

  - DOE did not explain how the range of experimental conditions provided were representative of repository conditions. Examples can be found in Sections 5.1.2 and 5.1.3 of this report.

  - DOE did not explain the technical basis used to extrapolate from the existing data. An example can be found in the second bullet in Section 5.1.2 of this report.

B. In some cases, DOE did provide a clear explanation of its technical basis but did not provide adequate technical information necessary to support that explanation. Technical information includes experimental data, analog information, analyses, and expert judgement. Examples of this situation follow:

- DOE did not provide technical information to cover the full range of conditions DOE assumed in the technical basis. Examples can be found in Section 5.1.2 and 5.3.1 of this report.

- DOE did not explain how information on analogous materials was appropriate for candidate material. Examples can be found in Section 5.1.5 of this report.

The team's determination that technical information was lacking was based on the information presented in the AMR and supporting references. The team did not consider whether the missing information would be available in other DOE documents (if not referenced in the AMR), whether activities were underway to collect this information, or whether alternative information or approaches could be used to support the technical basis. Further information about the concerns identified by the team for each AMR is provided in Section 5.0 of this report.

NRC staff will use risk information in the review of a LA to ensure the review focuses on the items that are most risk significant. For example, certain features (e.g., fracture data - Section 5.3.2 of this report) and processes (e.g., microbially induced corrosion - Section 5.1.2 and 5.1.3 of this report) are expected to be of low significance while others will be of high significance (e.g., stability of passive film on the waste package - Section 5.1.2 of this report); thus the level of information is expected to be greater for the items of higher significance. Although the overall significance of the three AMRs reviewed in this evaluation were considered to be of high or medium significance to repository performance, the significance of individual concerns related to specific technical information varies from low to high significance (e.g., high significance for waste package corrosion does not imply that all technical information regarding corrosion is of high significance). The NRC staff will consider risk information (e.g., performance assessment results, and identification and description of barriers important to waste isolation) during review of the LA to determine the level of information necessary to support the technical bases.

Finally, the team found a number of instances where DOE clearly explained in the AMRs the technical basis and provided the necessary technical information. For instance, the team found that DOE provided an adequate explanation of critical potentials which initiate localized corrosion of the waste package on a conservative basis. To validate long-term corrosion rates, DOE used uniform corrosion rates it obtained from electrochemical methods to corroborate the corrosion rates obtained from immersion tests.

3.3 AMR Development and Control Processes

The team identified a general concern regarding the implementation of Procedure AP-2.14Q, "Document Review," Revision 3 ICN 0. DOE's and BSC's checking and review process is a key and critical element in technical product development. The concerns found by the team during this evaluation, as presented in Section 5.0 of this report, could reasonably have been identified by a thorough technical review process by DOE. A lack of DOE checker and reviewer independence, time, and reviewer technical capability could have been contributing causes as to why DOE did not find the issues identified by the team. More information about the control process concerns identified by the team, for each AMR evaluated, is provided in Section 6.0 of this report.

3.4 Corrective Action

The team confirmed DOE's and BSC's findings that they have not been fully successful in carrying out effective actions to eliminate recurring concerns. As a result of recent trend analyses, BSC has determined that human performance was the primary contributor to concerns identified during Fiscal Year 2003. BSC determined that a large contributor to previous ineffective corrective actions was from not identifying and addressing human performance concerns. In the past, DOE and BSC have not fully considered and integrated human performance concerns in their root cause analysis and corrective action program efforts. Because of the new trend information, BSC plans to implement a formal integrated program to improve human performance. If successful, this human performance improvement program may increase the effectiveness of corrective actions to prevent concerns from recurring. More information about the concerns identified by the team for each AMR evaluated is provided in Section 7.0 of this report.

4.0 CONCLUSIONS

The team used its risk insights baseline to select three AMRs believed to be of high or medium significance to repository performance. The team identified some concerns with both the clarity of DOE's technical bases presented in the three AMRs evaluated and also with the presentation of sufficient technical information to support that explanation. These concerns could reasonably have been identified and corrected during the AMR checking and review process. The team also found concerns in the effectiveness of corrective actions. The number and similar pattern of concerns found in all three AMRs suggest that other AMRs may have similar limitations. The team believes that, if DOE continues to use their existing policies, procedures, methods, and practices at the same level of implementation and rigor, the LA may not contain information sufficient to support some technical positions in the LA. This could result in a large volume of requests for additional information in some areas which could extend the review process, and could prevent NRC from making a decision regarding issuing a construction authorization to DOE within the time required by law.

The conclusions of this evaluation are based on a focused review of three AMRs and supporting references. The team notes that additional information may exist in other DOE documents and alternative approaches could be used to address the identified concerns. However, DOE did not provide or reference this information in the AMRs evaluated by the team. An effective review process that documents such things as: (a) appropriateness of information to repository conditions; (b) selection and representativeness of data; (c) treatment of uncertainties; (d) justification for extrapolation and interpolation of data; and (e) consideration of alternative conceptual models would improve defensibility and transparency of DOE's technical bases and could also reduce the quantity of concerns NRC staff may find during the review of the LA.

U.S. NUCLEAR REGULATORY COMMISSION STAFF EVALUATION OF U.S. DEPARTMENT OF ENERGY ANALYSIS MODEL REPORTS, PROCESS CONTROLS, AND CORRECTIVE ACTIONS

EVALUATION REPORT

1.0 SCOPE

In order to assess the process being used by DOE to ensure the transparency of information in technical documents, an Evaluation Team from the U.S. Nuclear Regulatory Commission (NRC), NRC's Region IV office, and the Center for Nuclear Waste Regulatory Analyses (CNWRA) performed three targeted audits to independently evaluate the technical information in selected Analysis Model Reports (AMRs) and supporting information considered significant to be of high or medium significance to repository performance. Technical information includes field and experimental data, models, analyses, and justifications for any assumptions and conclusions presented by the U.S. Department of Energy (DOE). The staff used its risk insights baseline to select the AMRs believed to be of high or medium significance to repository performance. The team also evaluated the processes used in developing and controlling AMRs, and the effectiveness of recent corrective actions in eliminating recurring problems in the areas of models, software, and data. The team performed the evaluation at the U.S. Department of Energy (DOE) Management and Operating Contractor, Bechtel SAIC Company, LLC (BSC), facility in Las Vegas, Nevada. BSC is DOE's prime contractor and has the overall responsibility for developing the License Application (LA) for DOE.

This evaluation neither duplicates nor replaces the licensing review that NRC staff will conduct after DOE's submittal of its LA. Conclusions drawn from the results of this evaluation neither indicate NRC acceptance nor rejection of any DOE documents.

2.0 CONDUCT OF THE EVALUATION

The team identified for review the AMRs that were considered to be of high or medium significance to repository performance based on NRC's "Baseline of Risk Insights," June 5, 2003, and those DOE technical program areas considered to be of significance regarding repository performance.

The team focused on those AMRs that have completed the checking process described in DOE Procedure AP-2.14Q, "Document Review," Revision 3 ICN 0, and the processes that apply to the development and control of AMRs, as described in the latest revision to DOE/RW-0333P, "Quality Assurance Requirements and Description (QARD)." As a result of this process, NRC staff selected the following AMRs for evaluation:

1. "General and Localized Corrosion of the Waste Package Outer Barrier," ANL-EBS-MD-000002, Revision 2

2. "Commercial Spent Nuclear Fuel Waste Form Degradation Model," ANL-EBS-MD-000015, Revision 2

3. "Drift Degradation Analysis," EBS-MD-000027, Revision 2

The team used the guidance presented in the NUREG-1804, "Yucca Mountain Review Plan," Revision 2, July 2003, to develop the evaluation process and to identify applicable evaluation criteria. The team conducted an in-briefing at the beginning of each audit to inform DOE and BSC of the scope of the evaluation. During the performance of each audit the team met with DOE and BSC periodically to inform DOE and BSC of the evaluation progress and preliminary concerns. The team conducted an out-briefing at the end of each audit to inform DOE and BSC of the preliminary concerns identified during the evaluation. The list of NRC evaluation team members is presented in Attachment 1 to this report.

3.0 RISK INSIGHTS

The staff used its Baseline of Risk Insights to select the AMRs for this evaluation. In general, high significance is associated with features, events, and processes that will likely result in one of the following impacts: (a) affect a large number of waste packages; (b) significantly affect the release of radionuclides; or (c) significantly affect the transport of radionuclides through the geosphere or biosphere. Medium significance is associated with a lesser effect on waste packages, radionuclide releases, or radionuclide transport, and low significance is associated with minimal effect. Based on the Baseline of Risk Insights, staff focused its resources on the AMRs identified in Section 2.0 above, which contain analyses of features, events, and processes estimated to be of higher significance.

Within the scope of the evaluation, the staff assessed the information reported in each of the AMRs to improve its understanding of the implications for waste isolation capabilities of the repository system. The staff also evaluated the information to assess both the independent and collective impacts on the significance to waste isolation. Based on its current understanding and development of an updated risk-insights baseline, the staff maintains its current estimate of the significance of the information supporting corrosion of the waste package to be high. This is because the persistence of a passive film on the surface of the waste package continues to be significant to waste isolation. As a result of updating the risk-insights baseline work, waste form degradation rates and drift degradation have been revised from high to medium significance to waste isolation capabilities.

4.0 GOOD PRACTICES

The team found good practices during the evaluation, including the following:

- Excellent cooperation and support from all levels of DOE and BSC management.

- Technical support for the AMRs was greatly improved over what was available for the Total System Performance Assessment for Site Recommendation.

- The current AMRs were updated, are more comprehensive, and contained more data.

- BSC documented the concerns the team identified on Condition Reports and, in doing so, entered the concerns into DOE's Corrective Action Program.

- The Technical Data Management System (TDMS) and its associated data bases are outstanding tools for electronic access to data. Cross-referencing between the Corrosion

AMR and DOE's data repository was adequately accomplished through the use of the Document Input Reference System (DIRS) for the document and the Technical Data Information Form (TDIF) for each data set. File-naming conventions were stated and followed, thus facilitating transparency between laboratory output data files and spreadsheet files.

- BSC's Data Qualification Program was effective in identifying some of the existing data concerns in the AMRs.

- Software documentation was extensive.

- The Trending Program has been improved.

5.0 EVALUATION OF TECHNICAL INFORMATION

DOE had identified the AMRs evaluated by the team as being a part of its intended LA for a geologic repository at Yucca Mountain, Nevada. DOE had completed the checking process described in Procedure AP-2.14Q for each of the AMRs evaluated by NRC staff and the processes that apply to the development and control of AMRs, as described in the latest revision to QARD.

The team reviewed the AMRs identified in Section 2.0 and evaluated the data used to develop the models that are outputs to either the Total System Performance Assessment (TSPA), other computer codes, or other AMRs.

In order to assess the process being used by DOE to ensure the transparency of information in technical documents, the team evaluated the three AMRs identified in Section 2.0 above primarily in five main technical areas as described in the NUREG-1804. The team performed the evaluation of the technical information used in AMRs, using checklists based on applicable quality assurance (QA) program requirements and based on reviews of the selected AMRs conducted before the evaluation activities. Evaluation results are categorized with respect to the review methods contained in the NUREG-1804.

System Description and Model Integration

- The TSPA adequately incorporated important site features, physical phenomena, and couplings, and consistent and appropriate assumptions throughout the modeling abstraction process.

- The TSPA model abstraction identified and described aspects of the modeling that were important to repository performance, and included the technical bases for these descriptions.

- Assumptions were consistent between the modeling and other abstractions.

- Guidance provided in NUREG–1297, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program," November 1996, and NUREG–1298, SECY-99-074 - "Staff Review of U.S. Department of Energy Viability

Assessment for a High-Level Radioactive Waste Repository at Yucca Mountain, Nevada," March 11, 1999, and in other acceptable peer review approaches, was followed.

Verification that Data Are Sufficient for Model Justification

- The parameter values used were adequately justified.

- Data were sufficient to assess the degree to which features, events, and processes related to the modeling have been characterized and incorporated in the abstraction.

Data Uncertainty Characterization and Propagation

- Models used parameter values, assumed ranges, probability distributions, and bounding assumptions that were technically defensible, reasonably account for uncertainties and variabilities, and did not result in an under-representation of the risk estimate.

- The technical bases for the parameter values and ranges in the abstraction were technically defensible.

- Process-level models used to determine parameter values for the modeling were consistent with site characterization data, laboratory experiments, field measurements, and natural analog research.

- Uncertainty was adequately represented in parameter development for conceptual models and process-level models considered in developing the modeling, either through sensitivity analyses, conservative limits, or bounding values supported by data, as necessary.

- Where sufficient data did not exist, the definition of parameter values and conceptual models was based on appropriate use of expert elicitation, conducted in accordance with appropriate guidance such as NUREG–1563, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program," November 1996.

- Parameters or models that most influence repository performance, based on the performance measure and time period of compliance specified in 10 CFR Part 63, "Disposal of High Level Radioactive Waste in a Geologic Repository at Yucca Mountain, Nevada," were identified.

Model Uncertainty Characterization and Propagation

- Alternative modeling approaches of features, events, and processes were considered and were consistent with available data and current scientific understanding, and the results and limitations of alternative modeling approaches were appropriately considered in the abstraction.

- Sufficient evidence was provided that existing alternative conceptual models of features and processes that were important to waste isolation have been considered.

- Consideration of conceptual model uncertainty was consistent with available site characterization data, laboratory experiments, field measurements, natural analog information, and process-level modeling studies -- and the treatment of conceptual model uncertainty did not result in an under-representation of the risk estimate.

Model Support

- Calculations pertaining to the TSPA abstraction provided results consistent with output from detailed process-level models and/or empirical observations (e.g., laboratory testing, field measurements, and/or natural analogs).

5.1 Technical Evaluation Results, November 17-22, 2003 "General and Localized Corrosion of the Waste Package Outer Barrier" ANL-EBS-MD-000002, Revision 2

The team evaluated the technical information in the General and Localized Corrosion of the Waste Package Outer Barrier (Corrosion) AMR

5.1.1 System Description and Integration

The team did not identify any concerns in the area of System Description and Integration for the Corrosion AMR.

5.1.2 Data and Model Justification

The team identified seven concerns regarding the technical basis explanation and three concerns regarding the information supporting the technical basis.

- Assumption 5.1, which states that data acquired under fully immersed conditions are appropriate for conditions expected in the emplacement drifts, was not supported by data. Corrosion potentials used in the localized corrosion initiation model were dependent on the thickness of the diffusion layer. Increased oxygen reduction rates associated with thin water films may increase the corrosion potential and promote localized corrosion.

- Assumption 5.2 required that the material remains passive under the various testing conditions. Uniform corrosion rates were expected to remain low in the various testing environments where localized corrosion does not occur. Data included in the AMR suggest that significantly higher uniform corrosion rates may be observed under more aggressive testing conditions before localized corrosion is initiated. This may lead to an underestimate of uniform corrosion rates for more aggressive conditions.

- Assumption 5.5 implied that fully annealed welds behave similarly to base metal. No data on solution annealed welds were included in the AMR. Recent CNWRA independent testing suggests that solution annealing may be detrimental to the localized corrosion resistance of Alloy 22 welds.

- The rationale for inclusion and exclusion of data was unclear. For example, data from sodium fluoride and oxalic acid testing were excluded because conditions under which the data were collected were not considered representative of expected environments. However, the range of environments relevant to repository conditions was not referenced as input to this AMR.

- The criteria for the selection of data used in the AMR for the crevice corrosion repassivation potential model were not transparent for inclusion or exclusion of the Multi-Crevice Assembly samples prepared using Electrostatic Discharge Machining. Data from many of these samples were not presented in this AMR as a result of enhanced corrosion along the edges of the samples. In other cases, the data were used even though incomplete removal of the Electrostatic Discharge Machining surface was noted.

- Sufficient justification for inclusion of microbially influenced corrosion (MIC) as an enhancement to the general corrosion model was not presented in this AMR. MIC was included as an enhancement to the general corrosion model. Based on current scientific understanding, MIC is expected to alter localized corrosion susceptibility of container materials.

- MIC testing with microbes isolated from Yucca Mountain was performed at ambient temperatures. Tests were conducted at 25°C which is below the critical temperature for localized corrosion of Alloy 22. Temperatures of the waste packages after emplacement are expected to be above the critical temperature for localized corrosion.

- Limited data were obtained to evaluate the effects of fabrication processes on the localized corrosion susceptibility of the material. The data presented were obtained by testing in a narrow range of concentrated calcium chloride solutions that is likely to be very aggressive and may mask the effects of welding on the localized corrosion susceptibility.

- Sufficient data, analyses, and models to support the stability of a passive film over an extended period, considering passive dissolution rates and changes in oxide film compositions, were not provided in the AMR.

- MIC testing was conducted with microbes isolated from Yucca Mountain using mill annealed material. Welded materials are known to be more susceptible to MIC.

5.1.3 Data Uncertainty Characterization and Propagation

The team identified three concerns regarding the technical basis explanation.

- Data presented in the AMR indicate that surface preparation of the test specimens may alter corrosion rates and localized corrosion resistance. Data from specimens with non-standard preparation were used selectively and the uncertainty associated with this observation was not characterized. The actual surface condition of the waste packages after fabrication and closure was not tested.

- Data presented in the AMR does not appear to adequately characterize uncertainty in uniform corrosion rate measurements. Silica deposition on Long Term Corrosion Test Facility weight loss specimens appears to complicate corrosion rate measurements.

- Data presented in this the AMR for the MIC uniform corrosion rate enhancement factor does not appear to support the reported uniform distribution, ranging from 1 to 2. MIC enhancement factors for other alloys reported in the AMR range up to 200. Data provided in Data Tracking Number (DTN) LL991203505924.093 for 120 days indicate enhancement factors have been observed which are greater than 2 above corrosion rates obtained in sterile conditions, and indicate increasing uncertainty in the enhancement factor with time.

5.1.4 Model Uncertainty Characterization and Propagation

The team did not identify any concerns in the area of Model Uncertainty Characterization and Propagation for the Corrosion AMR.

5.1.5 Model Support

The team identified two concerns regarding the information supporting the technical basis.

- The crevice corrosion repassivation potential model presented in the AMR was not verified over its intended pH range of use. Equation 6-32 contains a parameter for pH dependence of crevice corrosion repassivation potential. Data are reported for tests conducted in solutions with pH ranging from 4.1 to 6.4. Attachment VII of this AMR referenced data reported by the CNWRA solutions, with the pH ranging from 6 to 8. However, the model is intended to be used for pH ranging from 2 to 12.

- The calculated corrosion rates presented in the AMR for the general corrosion rate model, which assume passive film stability, were not verified over the entire temperature range of intended use. The general corrosion rate model constructed the weight loss of Long Term Corrosion Test Facility specimens and the temperature dependence of the corrosion rate model using linear polarization resistance data. The reported temperature range of intended use ranges from 25 to 150°C. Calculated uniform corrosion rates are verified with long-term data for Alloy C, a predecessor to alloys C276 and C22, at 25°C.

5.1.6 Additional Reviews

The team reviewed documents associated with the Corrosion AMR. The "Technical Work Plan" provided guidance for the development of the revised Corrosion AMR and addressed model development and model validation. The draft "Proposed Work Plan," dated November 12, 2003, identified data needs and included additional localized corrosion testing of welded material, and in drift environment studies. The "Phase 2 Self Assessment" (initiated on November 11, 2003, and signed November 18, 2003) identified concerns with the technical adequacy of the Corrosion AMR. The "Aging and Phase Stability" AMR, Revision 1, was the only input to the Corrosion AMR.

5.1.7 Software Evaluation

The team found that DOE used Microsoft Excel 2000 and MATHCAD 2000 Professional directly in the Corrosion AMR. Both are commercial off-the-shelf software using standard statistical functions or having simple formulae entered by the user. Requirements for this type of software in these applications were that sufficient documentation of inputs, outputs, and formulae be available so that the calculations can be reproduced or verified. DOE successfully located the Excel files and .pdf versions of the MATHCAD files in the TDMS, and provided sufficient information regarding the software. The team verified a sample of calculation formulae and found the calculations to be properly entered into the spreadsheet cells.

The team extended the examination of data and calculations for the Corrosion AMR down to laboratory data and data analysis. The team found that corrosion data acquired at Lawrence Livermore National Laboratories (LLNL) had been analyzed to derive the corrosion rate using software associated with the laboratory equipment (Potentsiostat). Although LLNL verified the data acquisition function of the software during instrument calibrations, LLNL did not provide information (the formula) so that the corrosion rate calculation could be verified. LLNL rectified this condition during the audit through entries in a scientific notebook of the formula and verification that the calculation was by performing a duplicate calculation using Excel.

The team reviewed more complex software including "Aging and Phase Stability" AMR and found that LLNL had used DICTRA V.20 and Thermo-Calc V.M software. LLNL acquired and formally qualified these software packages. The team reviewed documentation for these software packages, including Software Activity Plans, Requirements Documents, Installation Test Plans, Validation Test Plans, and Validation Test Reports. The test reports included results from both the installation tests and validation tests. The team selected example problems (i.e., test cases) used for validation from the example problems provided in the software vendor's documentation. The team evaluated the use of the software by comparing the test cases that had been run to the application of the software in support of the report. The test cases appeared to adequately span the ranges of use of these software items. The team reviewed the "Aging and Phase Stability" AMR and confirmed it has sufficient information available so that the calculations performed by Thermo-Calc and DICTRA could be replicated.

5.1.8 Data Evaluation

The team evaluated a sample of data input DTNs to the Corrosion AMR. A methodical drill-down approach used various electronic databases to determine the traceability of data to source information.

The Corrosion AMR included 19 input data sets and two output data sets. Of the input data sets, BSC developed four (i.e., the data may have involved calculations or other manipulation) and acquired 15 (i.e., data that came directly from laboratory data or from other sources). In general, the acquired data sets included laboratory data acquisition files and corresponding spreadsheet files. LLNL processed the laboratory data before using them in the Corrosion AMR. Appropriate use and justification of the data are addressed in the technical section of this report. The team identified the following concerns regarding data traceability and transparency:

- The majority of data records had the qualification status of "To Be Verified" (TBV) because the records road maps had not been prepared. BSC identified this concern itself.

- One instance was found where data presented in the report (Table 6-10 of the Corrosion AMR) was not found in the cited DTN. Also, one instance was found of a typographical error that led to confusion of units for data mentioned in the document.

- Data classified as Technical Information had been used for direct input in many instances in this Corrosion AMR. Previously, data classified as Technical Information did not require data qualification. BSC identified this concern itself.

- Data for the threshold of MIC was categorized as "Reference-Only." No qualification process was required for Reference-Only data.

- In the development of a data set within a DTN, a modified database was used with the EQ3/6 software. The modified portions of the database were not adequately documented. However, the entire database was included as an electronic file within the DTN, thus facilitating reproducibility of calculations.

The team made the following observations regarding confusing approaches that hindered traceability and transparency:

- Data traceability and transparency were apparent only if the complete data chain (i.e., scientific notebooks, data sets with descriptions, and text of the Corrosion AMR) were reviewed concurrently. Recourse to the author shortened the process considerably because of the disparate locations of the information needed for complete tracing and understanding the data. Apparent instances of a lack of data transparency were noted when only one portion of the data chain (e.g., a scientific notebook) was reviewed.

- Data was traceable to the source, although not always by a direct pathway. Superseded data sets required more convoluted traces than would be anticipated at the starting point.

- Some scientific notebooks were not yet available in the DOE Data and Information Systems, but were obtained through the Records Processing Center.

- The DIRS and the TDIFs were manually, rather than automatically, updated when data were superseded. For example, source DTNs for a data set may be superseded without indications appearing on the TDIF. Supersession of data sets initiate an impact review of all the documents and data that were linked to the superseded data set. The impact review process was being linked to the Automated Technical Data Tracking system at the time of the evaluation.

- In some cases, DTNs contained both laboratory (i.e., raw) data as well as processed data, whereas in other cases, separate DTNs contained the processed data. This led to some confusion in tracing data and assessing data selection practices.

- One unqualified data set was listed as input to the Corrosion AMR; however, this was clearly indicated and documentation noted that the data qualification was nearing completion and the status would soon be changed.

5.2 Technical Evaluation Results, December 8-12, 2003
"Commercial Spent Nuclear Fuel Waste Form Degradation Model"
ANL-EBS-MD-000015, Revision 2

The team evaluated the technical information used in the "Commercial Spent Nuclear Fuel Waste Form Degradation Model" (CSNF) AMR. The team also reviewed the Radionuclide Release Model report. The team reviewed the model for the degradation of commercial spent nuclear fuel in the waste package resulting from contact with humid air or water under primarily oxidizing conditions.

5.2.1 System Description and Integration

The team did not identify any concerns in the area of System Description and Integration for the CSNF AMR.

5.2.2 Data and Model Justification

The team identified two concerns regarding the technical basis explanation:

- The commercial spent nuclear fuel corrosion rate was obtained by selecting a steady state portion of the release rate data for the alkaline region, and the initial portion of the release rate data for the acidic range. The technical bases for selecting the starting and ending points of the observed curves were not discussed in the CSNF AMR.

- The range of the effective surface area (or scaling factor) for the commercial spent nuclear fuel is based on data from the "Drip Test" method. However, the measured fractional releases from the drip tests are likely to be affected by at least four factors:

    - The possibility of radionuclide releases from the gap and grain boundaries,

    - The possibility of reduced matrix dissolution rates in the presence of ions such as calcium and silicate,

    - The possibility of reduced matrix dissolution rates with repository relevant seepage (drip) rates, and

    - The possibility of reduced matrix dissolution rates with partial protection by failed cladding.

    These factors could undermine the calculation of effective surface area. The technical bases for the assertion that the Drip Test method is acceptable for estimating effective surface area were not adequately discussed in the Report.

5.2.3 Data Uncertainty Characterization and Propagation

The team identified one concern regarding the technical basis explanation and one concern regarding both the technical basis explanation and the information supporting the technical basis.

- In Section 4.1.2 of the CSNF AMR, the "Single-Pass Flow-Through Test" method used to develop the "Radionuclide Release Model Report" has been shown to be inconsistent in round-robin tests. In addition, the method has been applied inconsistently among laboratories. Approval of an American Society for Testing and Materials method for "Single-Pass Flow-Through Tests" could add credibility and confidence to the flow-through data presented in the report.

- Review of drip-test data indicates several concerns, such as the loss of water in some of the experiments during several of the sampling intervals. Although this data was not used in the evaluation of release rates, the reliability and reproducibility of similar experimental results that were used in the analysis can be questioned if similar concerns occurred during those tests.

5.2.4 Model Uncertainty Characterization and Propagation

The team identified four concerns regarding the information supporting the technical basis:

- Since coefficients selected for the base model of CSNF dissolution have a poor regression fit, the coefficients for carbonate, temperature, and pH in the abstracted model should be further justified, using published data or other peer-reviewed information.

- The CSNF abstraction model does not represent the range of chemistries predicted by the in-package chemistry report (e.g., the acid-range model does not extend to the expected carbonate concentration close to neutral pH, and neither the acid-range nor alkaline-range models extend to temperatures of 95°C, which is the boiling point of water in the repository). Data used to formulate the models was limited to 75°C for the alkaline-range model and 25°C for the acid-range model. Temperatures and reaction conditions are important because the rate of a reaction increases exponentially with temperature and the rate of reaction may be greatly affected by the chemical composition of the solution.

- Latent oxidation of UO_2 to U_3O_8 under initially dry conditions, for long periods of time, is as likely as corrosion under humid or dripping conditions. If oxidation occurs under dry conditions, subsequent seepage of water into the waste package and contacting the commercial spent nuclear fuel could lead to relatively fast release of radionuclides, at least initially, compared to release under conditions of oxidative corrosion and release under wet conditions.

- Corrosion of commercial spent nuclear fuel under humid conditions before dripping is also likely. As in the concern directly above, subsequent seepage of water into the waste package and contacting the corroded commercial spent nuclear fuel could lead to relatively fast initial releases of radionuclides.

5.2.5 Model Support

The team identified two concerns regarding the information supporting the technical basis:

- The range of the data used for model validation may exceed the applicable range of the models. For example, some data collected at 10°C were used for model validation, whereas the lowest temperature used for calibration of the model was 25°C. Similarly, UO_2 dissolution data used in validation should be re-examined to assure that there is no influence of precipitation of secondary uranium minerals. In addition, the basis should be provided for using commercial spent nuclear fuel dissolution data collected in groundwater solutions containing ions such as calcium and silicate in the validation.

- One of the examples evaluated the commercial spent nuclear fuel dissolution at 30°C. This is an inappropriate example because waste package temperatures will not fall to such a low value within the 10,000-year regulatory time period.

5.2.6 Software Evaluation

BSC used Microsoft Excel 2000 and MATHCAD 2001 Professional directly in the CSNF AMR and "Radionuclide Release Model Report." Both software packages use standard statistical functions or have simple formulae entered by the user. The team located the necessary Excel files and MATHCAD files in the TDMS, and BSC provided the files to the team on a CDROM. The team used data from a sample of the sets in its confirmation of the regression equations for commercial spent nuclear fuel dissolution rates. The team found printouts of the Excel and Mathcad results in the Appendix to the CSNF AMR.

The team's examination of data and calculations for the CSNF AMR and Radionuclide Release Model Report extended down to laboratory data and data analysis. There was specialized software associated with the processing of raw instrument data that fed into tables presented in the CSNF AMR, but detailed evaluation of this software was not conducted.

5.2.7 Data Evaluation

The team evaluated data input to the CSNF AMR and Radionuclide Release Model Report that the technical members of the evaluation team selected, based on risk significance. A methodical drill-down approach used various electronic databases to determine the traceability of data to source information.

Of the input data sets included in this CSNF AMR, there were both developed data and acquired data. In general, the acquired data sets included laboratory data acquisition files and corresponding spreadsheet files. Processing of the laboratory data was done before use in the CSNF AMR and Radionuclide Release Model Report. The team identified the following concerns regarding the data:

- Tables A7 and A8 of the CSNF AMR were not cross-referenced to their input data sources.

- Tables 6.4-2 to 6.4-7 of the CSNF AMR were tabulated results of regression analyses. The data used in these regression analyses could not be tracked to the source.

- Table A6 refers to an incorrect DTN.

- Instantaneous release fraction data are contained in DTN MO0301ANLSF001.450. Tracking indicated that these data are located in ANL QAREF YMP/SF-3A-450. This document was not available in the TDMS.

5.3 Technical Evaluation Results, January 12-16, 2004
"Drift Degradation Analysis"
EBS-MD-000027, Revision 2

The team evaluated the adequacy of technical information used in the Drift Degradation Analysis AMR.

5.3.1 System Description and Integration

The team identified one concern regarding the information supporting the technical basis:

- The Drift Degradation Analysis AMR provided an incomplete consideration of event frequency. The analysis in the report shows a threshold response where there is essentially no effect in the lithophysal rock for a 5E-4/yr event, but a large effect for a 1E-6/yr event. Event frequencies between these two frequencies were not evaluated.

5.3.2 Data and Model Justification

The team identified three concerns regarding the technical basis explanation:

- The 3DEC modeling of nonlithophysal rocks in the Drift Degradation AMR contained broad statements that the nonlithophysal interval can be characterized as having a majority of non-persistent fractures. Fracture data from detailed DOE line surveys do not support the assertion that the majority of fractures in the middle nonlithophysal interval are non-persistent in nature.

- Fracture spacing data from detailed line surveys were not corrected for sampling bias before they were input into FracMan. The 3DEC fracture geometry is based directly on FracMan output and underestimates the number of sub-horizontal fractures. This underestimation of low-angle fractures in the FracMan simulation leads directly to an under representation of low-angle fractures in the 3DEC modeling of the nonlithophysal interval. As a result, the 3DEC models contain roughly eight times too few low-angle fractures. Since the low-angle fractures serve as primary release planes for rock, the 3DEC models significantly underestimate the amount of rockfall that is expected to occur in response to thermal and/or seismic loading. BSC staff provided an outline for a technical work plan indicating that they were aware of this concern and had plans to address it.

- Justification for the boundary conditions used in the thermomechanical model was not provided.

5.3.3 Data Uncertainty Characterization and Propagation

The team identified one concern regarding the technical basis explanation:

- The treatment of uncertainty and variability in the Drift Degradation AMR were not supported. Uncertainty and variability were frequently reduced or eliminated in the report with inadequate justification. Examples include:

- The data in Figure 148 (page 226) was reduced to constant values for each rock category (Table 45, page 228), when in fact the raw data shows significant variability. For example, rock category 4 assigns an unconfined compressive strength of 25 MPa and Young's Modulus of 15.3 GPa when the measured data (Table V-8) indicated a range of 12-34 MPa for strength and with a corresponding variation in Young's Modulus of approximately 5 to 20 GPa.

- The tensile strength data in Table V-6 on page V-9 are reduced to a mean value for use in the analysis, and justification is not provided in the Drift Degradation AMR.

- The variable data in Table V-7 on page V-11 was used to calculate single values of cohesion and friction angle. Justification was not provided in the Drift Degradation AMR for the data reduction.

- The variable data in Table V-4 on page V-6 was reduced to constant values of fracture stiffness. Justification is not provided in the Drift Degradation AMR for the data reduction.

- Seventy-six combinations of ground motions and rock representations were taken randomly from 1575 possible combinations, with insufficient justification in the Drift Degradation AMR that the sample size was representative.

The report authors were able to provide satisfactory explanations or point to work in progress for the last four examples; although, the report did not contain sufficient details.

5.3.4 Model Uncertainty Characterization and Propagation

The team identified one concern regarding the technical basis explanation:

- The impact of degraded materials properties was not fully propagated. The analysis evaluated the impact of the degradation of material properties (such as strength) and showed a large effect under certain conditions. Limited modeling results (load on the drip shield and drift shape for seepage) were propagated for abstraction to the performance assessment, but other effects (such as on environmental variables) were not. No limitations were stated on the use of the output of the Drift Degradation AMR. This AMR provided no discussion of the impact on the results. The authors are addressing this concern in a revision to this AMR.

5.3.5 Model Support

The team found two concerns regarding the technical basis explanation:

- The FracMan software simulation approach involved iterative calibration (i.e., FracMan inputs were adjusted to values that were inconsistent with the detailed line survey data). This approach was not supported in the Drift Degradation AMR. Required "input" values were not based on analysis of detailed line survey data. As a result, the FracMan software results were "non-unique" solutions that were treated as unique representations of fracture geometry in the 3DEC software models.

- FracMan software outputs were not quantitatively validated as specified in Section 7.8.2 of the Drift Degradation AMR. This requirement stated in part that "...developed synthetic fracture geometry is adequate if it is representative and has statistical similarity compared to detailed line survey data." Statistical similarity was not demonstrated, and as a result, the FracMan software representations of fracture geometry were not validated. CNWRA staff's statistical calculations show that the FracMan simulation results reported in the AMR (and used as direct input to the geomechanical modeling) were not quantitatively comparable to the measured fracture data. The "Summary Highlights of the NRC/DOE Technical Exchange Meeting on Repository Design and Thermal-Mechanical Effects Key Technical Issue," May 6-8, 2003, documents that DOE was aware of this concern.

5.3.6 Software Evaluation

The team examined software qualification reports, software configuration management practices, and use of UDEC, 3DEC, PFC2D, PFC3D, and FRACMAN software in development of the Drift Degradation AMR. The team identified four concerns regarding software:

- The team identified three instances where software were apparently used outside the range of qualification. Certain software functions used to generate quality-affecting data in the Drift Degradation AMR were not qualified.

  - The ability of 3DEC to function in interactive mode was not qualified as required by the test plan.

  - The PFC2D and PFC3D lithophysae modeling function was also not qualified as required by the test plan.

  - The UDEC Voronoi modeling function for thermal mechanical modeling was not qualified, but was used.

  BSC initiated Software Concern Reports to address these concerns.

- BSC used output from unqualified software in the Drift Degradation Analysis AMR. Specifically, BSC qualified UDEC, Version 3.10, Sub Release109 on September 9, 2002. The team identified UDEC sub releases 106 and 108 that were not qualified but were used to generate quality-affecting data for the Drift Degradation Analysis AMR.

- Itasca Consulting Group, Inc., produced sub releases for their suite of software; however, "Verification Reports," the "Software Baseline Report," and AMRs did not include a reference to these sub releases.

- The QARD, Revision 13, Supplement I.2.1.B.1, requires, in-part, that "...software verification shall be performed at the end of the Requirements, Design, Implementation, and Testing life cycle phases to ensure that the products of a given life cycle phase are traceable and fulfill the requirements of the previous phase and/or previous phases." Procedure AP-SI.2Q, "Qualification of Level A Software," Revision 1 ICN 1, did not address this requirement for the implementation life cycle phase. BSC performed verification at the end of the testing phase for both implementation and testing. BSC was in the process of revising the software management procedure and was expecting to address this concern.

5.3.7 Examination of Data

The team evaluated data inputs to the Drift Degradation AMR that were selected based on risk significance. The team traced approximately 25 percent, or 19, of the input DTNs during the evaluation. For those DTNs accessed, a methodical drill-down approach used various electronic databases to determine the transparency of data use and traceability of data to source information. The team identified five concerns regarding the technical basis explanation:

- The team found the traceability and transparency of simulation data to be inadequate. Input and output files for thermal-mechanical and thermohydrological simulations completed in the Drift Degradation AMR were provided in an output DTN, with neither description nor reference to a scientific notebook. Short, descriptive subdirectory names provided the only traceability to figures and tables presented in the Drift Degradation AMR. Manipulated output data, summary tables, and figures could only be reconstructed by extracting data with the aid of the user manual for the software used to generate the output. Scientific notebooks were not used to document the analyses.
- No FracMan input and output files were included in data files. The information presented in a scientific notebook mentioned during the evaluation did not aid traceability and transparency of FracMan simulations and translation to thermal-mechanical model inputs. The scientific notebook were neither cited in any output DTN nor in the Drift Degradation AMR. Traceability and transparency of the FracMan work may be transferred to a fracture synthesis AMR currently being prepared.

- The transparency of parameter input tables to DTNs or reports could not be achieved without recourse to the analyst. Some columns of parameter values required further analyst explanation for: (a) the basis for data selection from the cited DTN; and (b) the manipulation of the input DTN data to those used in the analyses described in Section 6 and 7 of the Drift Degradation AMR.

- BSC used Reference Only data as direct input in one instance. Specifically, a value of "C" from Dershowitz and Herda was listed as Reference Only data but was used as direct input, thus avoiding the data qualification process.

- The team encountered access difficulties to some files within output DTN. The files were identified as “read-only” and "being edited by," thereby preventing access. The process for submitting data sets to the data base system did not include a checking process for read access for all submitted files.

- The team identified a number of instances where the traceability of the analysis was insufficient, which influenced the ability of a reviewer to evaluate whether data and model justification were sufficient:

- The value of Young's modulus of 24.5 GPa for the UDEC model was not traceable (page 141). The report incorrectly stated Section V.4.4 instead of V.4.2 and did not provide an explanation of where the data came from.

- Insufficient documentation was provided of how the temperatures calculated using NUFT software was transferred to UDEC and FLAC software for conducting thermally-induced drift degradation analysis.

- Insufficient documentation was provided to explain how the values of bulking factors given in Table 40 was calculated (page 196). The analysts said they did not maintain scientific notebooks documenting the analysis.

- The documentation of the conversion process for FracMan software output to 3DEC software input was not traceable. The original FracMan software output files were not provided in the Drift Degradation AMR and the details of conversion calculations were not presented. As a result, the team was unable to trace the process from FracMan software output to 3DEC software input.

5.4 Conclusion on Technical Information Evaluation

In order to assess the process being used by DOE to ensure the transparency of information in technical documents, the team evaluated three AMRs primarily in five main technical areas as described in the NUREG-1804, "Yucca Mountain Review Plan," Revision 2, July 2003: (a) System Description and Integration; (b) Data and Model Justification; (c) Data Uncertainty Characterization and Propagation; (d) Model Uncertainty Characterization and Propagation; and (e) Model Support. NRC regulations at 10 CFR Part 63 require DOE to support its LA for a proposed repository with technical bases. To review DOE's potential LA, the NRC staff will need to understand DOE's explanation of its technical bases and find that DOE has supplied sufficient technical information to justify that explanation. The team identified some concerns with both the clarity of explanation of DOE's technical bases presented in the AMRs evaluated and also with the presentation of adequate technical information necessary to support that explanation. These concerns are summarized under the following two categories.

A. In some cases, DOE did not explain its technical basis such that NRC staff could understand how DOE reached its conclusions. Because DOE's explanation of its technical basis was not clear, the team could not determine if the associated technical information was adequate. Examples of this situation follow:

   - DOE selected a single value or a portion from a range of data without sufficient justification. Examples can be found in Sections 5.2.2 and 5.3.3 of this report.

   - DOE did not explain how the range of experimental conditions provided were representative of repository conditions. Examples can be found in Sections 5.1.2 and 5.1.3 of this report.

   - DOE did not explain the technical basis used to extrapolate from the existing data. An example can be found in the second bullet in Section 5.1.2 of this report.

B. In some cases, DOE did provide a clear explanation of its technical basis but did not provide adequate technical information necessary to support that explanation. Technical information includes experimental data, analog information, analyses, and expert judgement. Examples of this situation follow:

- DOE did not provide technical information to cover the full range of conditions DOE assumed in the technical basis. Examples can be found in Section 5.1.2 and 5.3.1 of this report.

- DOE did not explain how information on analogous materials was appropriate for candidate material. Examples can be found in Section 5.1.5 of this report.

The team's determination that technical information was lacking was based on the information presented in the AMR and supporting references. The team did not consider whether the missing information would be available in other DOE documents (if not referenced in the AMR), whether activities were underway to collect this information, or whether alternative information or approaches could be used to support the technical basis.

NRC staff will use risk information in the review of a LA to ensure the review focuses on the items that are most risk significant. For example, certain features (e.g., fracture data - Section 5.3.2 of this report) and processes (e.g., microbially induced corrosion - Section 5.1.2 and 5.1.3 of this report) are expected to be of low significance while others will be of high significance (e.g., stability of passive film on the waste package - Section 5.1.2 of this report); thus the level of information is expected to be greater for the items of higher significance. Although the overall significance of the three AMRs reviewed in this evaluation were considered to be of high significance, the significance of individual concerns related to specific technical information varies from low to high significance (e.g., high significance for waste package corrosion does not imply that all technical information regarding corrosion is of high significance). The NRC staff will consider risk information (e.g., performance assessment results, and identification and description of barriers important to waste isolation) during review of the LA to determine the level of information necessary to support the technical bases.

Finally, the team found a number of instances where DOE clearly explained in the AMRs the technical basis and provided the necessary technical information. For instance, the team found that DOE provided an adequate explanation of critical potentials which initiate localized corrosion of the waste package on a conservative basis. To validate long-term corrosion rates, DOE used uniform corrosion rates it obtained from electrochemical methods to corroborate the corrosion rates obtained from immersion tests.

6.0 ADEQUACY OF AMR DEVELOPMENT AND CONTROL PROCESS

The team evaluated important quality-affecting processes associated with the production of the AMRs evaluated by the team to determine the overall effectiveness of the processes in developing and controlling those technical products. The team evaluated such processes as planning and development, documentation and traceability, use of software and data, model validation and analysis, and model checking and review. The team focused its evaluation of development and control processes by reviewing the adequacy and implementation of the following procedures:

- AP-SIII.1Q, "Scientific Notebooks," Revision 2 ICN 0
- AP-SIII.9Q, "Scientific Analysis," Revision 1 ICN 1
- AP-SIII.10Q, "Models," Revision 2 ICN 0
- AP-2.14Q, "Document Review," Revision 3 ICN 0

The team identified a general concern regarding the implementation of Procedure AP-2.14Q, "Document Review," Revision 3 ICN 0. DOE's and BSC's checking and review process is a key and critical element in technical product development. The concerns found by the team during this evaluation, as presented in Section 5.0 of this report, could reasonably have been identified by a thorough technical review process by DOE. A lack of DOE checker and reviewer independence, time, and reviewer technical capability could have been contributing causes as to why DOE did not find the issues identified by the team.

7.0 EFFECTIVENESS OF CORRECTIVE ACTION

The team evaluated certain corrective actions to determine their effectiveness in preventing the recurrence of conditions adverse to quality. The team focused primarily on recurring concerns identified in the areas of model validation, software, and data.

7.1 Model Validation

In the area of model validation, DOE issued Corrective Action Report (CAR) BSC-01-C-001 (CAR 001) on May 3, 2001. In CAR 001, DOE stated that the results of its evaluation of AMRs that support the Total System Performance Assessment for Site Recommendation (TSPA-SR) identified systematic examples of inadequate model validation in 18 of 24 model validations examined. Regarding this same concern, on May 17, 2001, NRC staff issued a letter to DOE stating that NRC staff specifically identified technical errors and inconsistencies between the TSPA-SR documents, the underlying AMRs, the associated GoldSim computer code results, and associated hand calculations. DOE implemented actions to correct the identified concerns and prevent them from recurring.

DOE conducted an audit of the AMR process on October 21-31, 2003. DOE intended to use some of the information obtained during the audit to verify successful implementation of corrective action regarding CAR 001. However, during this audit, DOE found 25 percent of the AMRs evaluated to be unacceptable. The findings from this audit indicated that the actions taken to prevent the concerns identified in CAR 001 from recurring were not effective. Because of the extent and nature of the concerns recently identified by DOE in its audit, CAR 001 remains open.

In response to the findings of the audit of the AMR process, DOE and BSC are performing independent reviews of the remaining AMRs supporting Total System Performance Assessment for License Application (TSPA-LA) not previously reviewed during the audit. The purpose of these reviews was to determine compliance with the requirements of model validation procedures.

7.2 Software

In the area of software, DOE issued CAR BSC-01-C-002 (CAR 002) on June 12, 2001. In CAR 002, DOE stated that there was an indication of a lack of nuclear culture and a failure of the implementation of the QA program related to software. Further evaluation of the findings and the extent of the condition by DOE proved this to be true. DOE implemented actions to correct the identified concerns and prevent them from recurring.

DOE conducted an audit of the software process on June 2-13, 2003. DOE intended to use some of the information obtained during the audit to verify successful implementation of corrective action regarding CAR 002. However, during this audit, DOE identified 7 of 28 software process areas as ineffective: 5 marginally effective; and 2 indeterminate. The findings from this audit indicate that the actions taken to prevent the concerns identified in CAR 002 from recurring were not effective. In response to these identified recurring concerns, BSC is performing an independent verification and validation of all software that will support the TSPA-LA. Because of the extent and nature of the concerns DOE identified in its audit, CAR 002 remains open.

More recently, DOE performed a surveillance on January 20-29, 2004, focusing on the use and control of in-process software that was preliminary (not yet qualified) and its preliminary output, identified as TBV. DOE conducted this surveillance as a result of Condition Report (CR) 17, issued on April 30, 2003, regarding the control of in-process software and preliminary TBV output. The DOE surveillance team found that in-process software and preliminary TBV output was used in BSC-approved AMRs that will support the TSPA-LA. The surveillance team's preliminary findings include, along with other concerns, a lack of procedure controls in tracking preliminary output from in-process software; a lack of determining whether in-process software was adequate for its intended use; and a lack of determining if in-process software was used within its validation range. DOE has committed to use only qualified software and validated data in the LA.

7.3 Data

In the area of data, BSC issued CAR BSC(B)-03-C-107 (CAR 107) on March 14, 2003. In CAR 107, BSC documented numerous examples of Deficiency Reports and CARs related to the adequacy of data used in AMRs. In response to the concerns identified in CAR-107 BSC implemented, and was currently conducting, a Data Confirmation Program to confirm the qualification status and proper application of all data within each AMR directly used as input for the TSPA-LA.

7.4 Path Forward

To address the concerns identified in CAR 001, CAR 002, and other recurring concerns, DOE issued its MII on July 19, 2002. The MII charts DOE's path forward for overall improvements.

In response to one of the elements of the MII, BSC implemented an updated corrective action program (CAP) on September 23, 2003, in the form of Procedure AP-16.1Q, "Condition Reporting and Resolution," Revision 7. Associated with the updated CAP, BSC implemented updated processes for "Causal Analysis and Corrective Action Plan Development," AP-16.4Q, Revision 3, and "Trend Evaluation and Reporting," AP-16.3Q, Revision 3 ICN1. BSC's first trend evaluation report, issued in November 2003, trended all QARD-related CRs identified in Fiscal Year 2003. BSC reported that "The results of the analysis indicated the Human Performance/Skill Based Errors are the principal causal factors for CRs observed in Fiscal Year 2003. The dominant factors within this cause category are less-than-adequate self-checking and omitting steps in the procedure."

In the past, DOE and BSC have not fully considered and integrated human performance concerns in their root cause analysis and CAP efforts. Based on new information, DOE and BSC believes that a large contributor to previous ineffective corrective actions was not identifying and addressing human performance concerns. As a result of this trend evaluation, BSC issued CR 1291 (now CR 1497) on November 26, 2003, which states that "The project does not have a formalized and integrated human performance improvement program." BSC assigned responsibility to the Manager of Organizational Assurance and committed resources to develop and implement an effective program to improve human performance. If successful, this program may improve future effectiveness of corrective actions in eliminating certain recurring concerns.

7.5 Conclusions on the Effectiveness of Corrective Action

The team confirmed DOE's and BSC's findings that they have not been fully successful in carrying out effective actions to eliminate recurring concerns. As a result of recent trend analyses, BSC has determined that human performance was the primary contributor to concerns identified during Fiscal Year 2003. BSC determined that a large contributor to previous ineffective corrective actions was from not identifying and addressing human performance concerns. In the past, DOE and BSC have not fully considered and integrated human performance concerns in their root cause analysis and corrective action program efforts. Because of the new trend information, BSC plans to implement a formal integrated program to improve human performance. If successful, this human performance improvement program may increase the effectiveness of corrective actions to prevent concerns from recurring. More information about the concerns identified by the team for each AMR evaluated is provided in Section 5.0 of this report.

8.0 CONCLUSIONS

The team used its risk insights baseline to select three AMRs believed to be of high or medium significance to repository performance. The team identified some concerns with both the clarity of DOE's technical bases presented in the three AMRs evaluated and also with the presentation of sufficient technical information to support that explanation. These concerns could reasonably have been identified and corrected during the AMR checking and review process. The team also found concerns in the effectiveness of corrective actions. The number and similar pattern of concerns found in all three AMRs suggest that other AMRs may have similar limitations. However, the team believes that, if DOE continues to use their existing policies, procedures, methods, and practices at the same level of implementation and rigor, the LA may not contain information sufficient to support some technical positions in the LA. This could result in a large volume of requests for additional information in some areas which could extend the review process, and could prevent NRC from making a decision regarding issuing a construction authorization to DOE within the time required by law.

The conclusions of this evaluation are based on a focused review of three AMRs and supporting references. The team notes that additional information may exist in other DOE documents and alternative approaches could be used to address the identified concerns. However, DOE did not provide or reference this information in the AMRs evaluated by the team. An effective review process that documents such things as: (a) appropriateness of information to repository conditions; (b) selection and representativeness of data; (c) treatment of uncertainties; (d) justification for extrapolation and interpolation of data; and (e) consideration of alternative conceptual models would improve defensibility and transparency of DOE's technical bases and could also reduce the quantity of concerns NRC staff may find during the review of the LA.

9.0 APPLICABLE REFERENCES

- ANL-EBS-MD-000002, Revision 2, "General and Localized Corrosion of the Waste Package Outer Barrier"
- ANL-EBS-MD-000015, Revision 2, "Commercial Spent Nuclear Fuel Waste Form Degradation Model"
- EBS-MD-000027, Revision 2, "Drift Degradation Analysis"
- Code of Federal Regulations, 10 CFR Part 63, "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada"
- U.S. Nuclear Regulatory Commission, NUREG-1804, "Yucca Mountain Review Plan," Revision 2, July 2003
- U.S. Nuclear Regulatory Commission, Baseline of Risk Insights, June 5, 2003
- U.S. Nuclear Regulatory Commission, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program," NUREG–1297, November 1996
- U.S. Nuclear Regulatory Commission, SECY-99-074 - "Staff Review of U.S. Department of Energy Viability Assessment for a High-Level Radioactive Waste Repository at Yucca Mountain, Nevada," NUREG–1298, March 11, 1999
- U.S. Nuclear Regulatory Commission, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program," NUREG–1563, November 1996
- AP-SIII.1Q, "Scientific Notebooks," Revision 2 ICN 0
- AP-SIII.9Q, "Scientific Analysis," Revision 1 ICN 1
- AP-SIII.10Q, "Models," Revision 2 ICN 0
- AP-2.14Q, "Document Review," Revision 3 ICN 0
- AP-16.1Q, "Condition Reporting and Resolution," Revision 7

10.0 ACRONYMS

AMR	Analysis Model Report
BSC	Bechtel SAIC Company, LTD
CAP	Corrective Action Program
CAR	Corrective Action Report
CNWRA	Center for Nuclear Waste Regulatory Analyses
CR	Condition Report
CSNF	Commercial Spent Nuclear Fuel
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
DTN	Data Tracking Number
LA	License Application
LLNL	Lawrence Livermore National Laboratories
MIC	Microbially Influenced Corrosion
MII	Management Improvement Initiatives
NRC	U.S. Nuclear Regulatory Commission
QA	Quality Assurance
QARD	Quality Assurance Requirements Document
TBV	To Be Verified
TDIF	Technical Data Information Form
TDMS	Technical Data Management System
TSPA	Total System Performance Assessment
TSPA-LA	Total System Performance Assessment for License Application
TSPA-SR	Total System Performance Assessment for Site Recommendation

ATTACHMENT 1

EVALUATION TEAM MEMBERS

"General and Localized Corrosion of the Waste Package Outer Barrier"

T.	Matula	NRC, Evaluation Team Leader
B.	Spitzberg	NRC, Management Liaison
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R.	Fedors	CNWRA, Data Evaluation
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J.	Petrosino	NRC, Control Processes Evaluation
R.	Latta	NRC, Corrective Action Evaluation
V.	Everett	NRC, Corrective Action Evaluation
T.	Trbovich	CNWRA, Corrective Action Evaluation

"Commercial Spent Nuclear Fuel Waste Form Degradation Model"

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T.	Ahn	NRC, Technical Evaluation
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"Drift Degradation Analysis"

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K.	Smart	CNWRA, Technical Evaluation
R.	Folck	CNWRA, Software Evaluation
R.	Fedors	CNWRA, Data Evaluation
R.	Brient	CNWRA, Control Processes Evaluation and Corrective Action Evaluation